WEATHER ON TARGET

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LONG-TERM GOALS

The long term goal of this project is to develop tools for the automated analysis and nowcasting of conventional and remotely-sensed meteorological data, primarily for use at regional forecast centers, and aboard ship in remote littoral regions in which the Navy operates. In contrast to predicting weather out to several days (the purpose of numerical weather prediction), the purpose here is to assess current weather conditions at scales smaller than the grid spacing that limits numerical weather products. There is an emphasis on the recognition and analysis of clouds, and determining their locations and heights using both remote sensing and by calibrating output from regional weather prediction models. Improved nowcasts of parameters such as wind, visibility, and types and levels of cloudiness in the battlegroup area will provide an augmented capability for Navy operations, specifically, and for command and control, in general.

OBJECTIVES

Our objectives include the development of a satellite cloud classification procedure for use over land, to supplement a previously-completed overwater classifier (see Aha and Bankert, 1997) and thus provide automated imagery analysis on both sides of the littoral interface. A second objective is to develop a method for determining biases in cloud base height forecasts from the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). COAMPS is the replacement for the Navy's regional model, the Navy Operational Regional Atmospheric Prediction System (NORAPS), and features high resolution, nested grids, and nonhydrostatic vertical motion. Explicit prediction of cloud base height is the goal.

APPROACH

Our approach to satellite cloud classification is to use computer vision, whereby computed features that mimic human visual analysis provide the training components for an automated classifier. Our approach for cloud base height forecasts is to apply knowledge discovery from databases (KDD) technology to COAMPS forecast fields. We intend to apply KDD to improve model output by discovering, and correcting, model biases (Hadjimichael, 1997). In contrast to model output statistics (MOS), the resulting procedure would involve only model output variables at the forecast time, and would not require local observations; this distinction is important for Navy applications where conventional surface observations may be unavailable.

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WORK COMPLETED

Based upon the overland, world-wide Advanced Very High Resolution Radiometer (AVHRR) cloud imagery database that was developed in FY96, the overland cloud classifier has been completed. This classifier, when combined with the previously-completed overwater classifier, provides an automated tool to assist forecasters in the analysis of orbiting AVHRR satellite imagery anywhere in the world. In addition to these classifiers, which are valid only during the daytime when both visible and infrared imagery are available, two additional classifiers were developed for nighttime use. These classification schemes use only infrared imagery and produce overall classification accuracies comparable to those in the daytime.

The work completed earlier in the development of the Satellite Image Analysis Meteorological Expert System (SIAMES), an expert system to aid a user in the meteorological interpretation of satellite cloud patterns, has been published (Fett et al., 1997).

The COAMPS knowledge discovery project will tie COAMPS model fields to cloud base observations along the California coastline. A data collection procedure has been developed, with two independent continuous sources of observation data for the central/southern California coast: Tinker Air Force Base, and the Air Force Global Weather Command (AFGWC) via the Master Environmental Library. COAMPS model 12-hour-interval output is also being collected for the same region, for those 9 km grid points surrounding the observation stations. Preprocessing routines have been written to reduce and prepare the data for study, and to associate grid point data with observation data at each relevant site. Several available data mining technologies were selected, reviewed, and analyzed in terms of applicability to the data and problem. An initial analysis has been performed with one commercial data mining package.

RESULTS

This year's completed cloud classifier for overland daytime imagery is only slightly less accurate (82.3 vs. 87.1% for 10 cloud classes) than that for the overwater classifier. (See Figure 1 for example daytime image that covers both water and land.) This result, based upon 1527 cloud samples (expertly labeled) from 12 geographic regions, is better than was anticipated because of the expected difficulty of classifying clouds over numerous land background types. Overwater backgrounds, although differing in temperature, appear similar. Overland backgrounds, however, not only have a greater temperature range but also differ in their visual appearance (albedo). Losing only five percent in accuracy was a welcome result. Five-class (high, middle, low, vertical/precipitating, clear) results are similar (89.3 vs. 94.1%).

In order to allow for 24-hour classifications, a nighttime classifier was developed. Nighttime imagery was simulated by using only the infrared portion of the daytime imagery. Interestingly, overwater classification accuracy fell more than seven percent while overland accuracies fell only slightly (79.9 vs. 82.2%). One interpretation of this disparity is that the infrared is more important in discriminating cloud types overland; that surface temperature variations are so much larger overland than overwater would tend to support this hypothesis.

Because the data gathering stage of our data mining effort has required investigation of five different sources of data, our data mining effort with COAMPS has progressed only slightly beyond the data gathering stage. Tinker Air Force Base has been identified as a reliable source of surface observation data and is providing us with hourly observations from 15 stations in coastal California. From our evaluation of data mining software, we conclude that no high-quality, inexpensive, commercial data mining software is available. Excellent commercial software does exist, but at a high price. Therefore, we plan to pursue public domain and research level software.

IMPACT

The automated day/night cloud classifiers are intended for use at regional weather facilities and aboard ship. These aids will provide easy-to-use depictions (see Figure 1) of cloud type and height of cloud patterns visible from orbiting AVHRR sensors. Because cloud base height is, arguably, the key parameter affecting tactical air operations, success in the work just started determining COAMPS cloud height biases will be of vital use during any training exercise or conflict.

TRANSITIONS

The overwater/overland day/night automated cloud classifications have been transitioned to 6.4 (PE 603207N, as managed by SPAWAR PMW-185) and are being readied for presentation on the world-wide web. Initial feedback will be solicited from the Third Fleet in San Diego, based upon imagery downloaded in Monterey for the west coast. The next area of testing will likely be the U. S. east coast and later for the Mediterranean, once NSDS-E is available at Rota. Results from the COAMPS knowledge discovery project are planned for transition in FY99.

RELATED PROJECTS

This work is coordinated with a parallel research effort being conducted with "Core" 602435N funding (NRL base funding). That work, similar to the research reported here, emphasizes the use of artificial intelligence technologies, such as expert systems and computer vision, to automate the identification, interpretation, and prediction of weather parameters important to tactical operations. The work performed under both of these 6.2 efforts is further supported by PE 603207N (6.4) for implementation into an operational product (SPAWAR PMW-185). Other related research (also under PE 603207), funded through Point Mugu, is supporting the development of an expert system (ExperDuct) for the prediction of atmospheric electromagnetic ducting (SPAWAR PMW-185).

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Aha, D. W., and R. L. Bankert, 1997: Cloud classification using error-correcting output codes. *Artificial Intelligence Applications: Natural Resources, Agriculture, and Environmental Science*, 11, 13-28.

Fett, R. W., M. E. White, J. E. Peak, S. Brand and P. M. Tag, 1997: Application of hypermedia and expert system technology to Navy environmental satellite image analysis. *Bull. Amer. Meteor. Soc.*, **78**, 1905-1915.

Hadjimichael, M., 1997: A model for generalization. Proceedings, Fifth International Workshop on Rough Sets and Soft Computing. Research Triangle Park, NC, 1-5 March 1997, **3**, 177-180.

WWW display for cloud classification soon to be available at http://www.nrlmry.navy.mil. Example image for ten-class classification is shown in Figure 1.

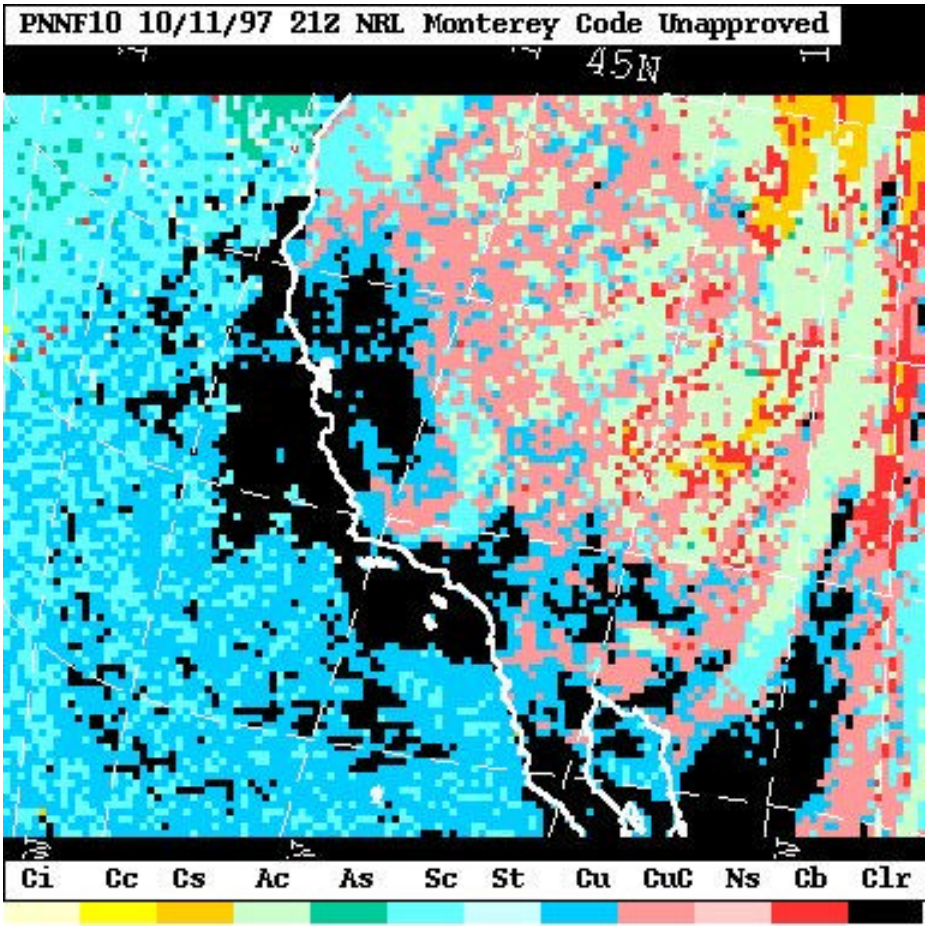

Figure 1. Example display of daytime cloud classification (valid at 21Z on 22 Oct 97) product, including both ocean and land classifications, for the west coast of the U.S. (being readied for evaluation by the Third Fleet in San Diego). Although much is lost in this black and white production of the color image, this depiction does show the areal coverage and detail possible from this product.